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Energy expenditure, television viewing and obesity

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OBJECTIVE: To measure energy expenditure (EE) of television viewing, sitting, and resting and duration of self-selected television viewing in obese and non-obese men and women.
DESIGN: Cross-over randomized study consisting of two separate 24-h stays in a whole-room indirect calorimeter.
SUBJECTS: 123 obese and non-obese healthy men and women (age: 38 ± 9, BMI: 29.4 ± 7.9)
MEASUREMENTS: Rates of energy expenditure during resting (RMR), sitting (EE_{sit}) and television viewing (EE_{tv}) using indirect calorimetry technique on two separate 24-h stays in a whole-room indirect calorimeter. Physical activities and work of body movements during these periods using a large force platform system located inside the calorimeter.
RESULTS: Rates of EE for television viewing, adjusted for differences in body composition were 18% higher than resting metabolic rate (RMR), but similar to rates of other sedentary activities. There were no significant differences between obese and non-obese subjects in metabolic rates during resting, television viewing, and other sedentary activities. Average time of self-selected television viewing was significantly greater in obese than in non-obese subjects and also in women than in men.
CONCLUSION: EE rate for television viewing in adults is higher than RMR and similar to other sedentary activities. Obese adults choose television viewing as a form of leisure activity more often than non-obese individuals and as a result they could significantly reduce other forms of physical activities and total daily EE.

Keywords: energy expenditure; television viewing; obesity; adults

Introduction

Television viewing has become such a popular daily event that its associated inactive physical status has caused public concerns about its role in obesity development.[1–4] According to recent estimates, adults in the United States view an average of 25–40 h of television/week.[5] Men who viewed television for more than 3 h/day were twice as likely to be obese as those who viewed less than 1 h/day.[6] Similarly, women who reported 3–4 h of television viewing/day showed almost twice the prevalence of obesity.[7] It was unclear, however, whether viewing television contributed to obesity development of men and women viewed television more frequently because they were obese. Nevertheless, it has been shown that there is a definite link between television viewing and risk of obesity.[8–11] The association between television viewing and decreased time for physical activity and increased energy intake has begun to receive more attention recently.[12–14] Although several studies have suggested that television and obesity are related, little is known about the way in which television viewing affects energy balance. It may be related to physical activity, energy expenditure, dietary intake or some combination of these.[15–18] Disproportional decrease in energy expenditure has been noted among obese children while viewing television in one study[19] but not in another.[20] To our knowledge, the rate of energy expenditure during self-selected television viewing in adult population has not been examined. Furthermore, differences in rates of energy expenditure between television viewing and other similar sedentary physical activities in adults have not been elucidated.

One purpose of the present study was to compare the rate of energy expenditure (EE) during television viewing and other forms of similar sedentary activities between obese and non-obese men and women. Second purpose was to compare duration of self-selected television viewing in these groups. In addition, the impact of exercise/physical activities on rates of EE during television viewing and other sedentary activities and on duration of self-selected television viewing was assessed. An activity–energy measurement system (AEMS) which is composed of a whole-room indirect calorimeter, a large force platform for physical activity measurement located inside the calorimeter, and an electronic sensor/switch system for behavioral monitoring, was used to quantify the above criteria.

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Methods

Subjects

One hundred and twenty-three subjects (51 men and 72 women, aged 20–50 years) were recruited from Nashville area by advertisement in the Vanderbilt University biweekly periodical, on local television stations, by poster, or through informal contacts. Subjects received written information about the nature and purpose of the study. Signed informed consent, which was approved by the Committee for the Protection of Human Subjects at Vanderbilt University, was obtained before their participation in the study. Subjects were admitted to the Clinical Research Center (CRC) of Vanderbilt University Medical Center. Prior to scheduling to the stay in the whole-room indirect calorimeter, all volunteers answered a questionnaire concerning their present health status, nutritional status, smoking and drinking behavior, habitual activity patterns and physical activities. Subjects were eligible for participation if they were apparently healthy with no evidence of past or present thyroid disorders and diabetes mellitus, did not use drugs known to affect energy metabolism, were eating a normal balanced diet, and were non smokers. To minimize an intraindividual effect of the menstrual cycle on RMR, both measurements (normal and active days) in women were planned in the same, either follicular or luteal, phase of the cycle. All selected subjects were required to maintain their normal pattern of diet and activity during the two week experimental period, except during one active day when 24-h energy expenditure was measured inside the whole-room indirect calorimeter. The cut-off point for classification of the subjects as being obese was set at BMI higher than 30 for both men and women.[21]

Experimental design

The study consisted of two 24-h stays for each subject in a whole-room indirect calorimeter (the chamber) separated by 5–7 days. Subjects were required not to engage in planned strenuous physical activity for 2 days prior to a stay in the room calorimeter to avoid the influence of post-exercise effect on energy expenditure During one day of chamber stay (the normal day), the subject was asked to structure his/her activities pattern as close as possible to their normal daily routine while in the whole-room calorimeter. Relatively small space inside the room calorimeter could, however, decrease subject's activity level and duration of some activities when compared to his/her working or home environment. To compensate for this effect, during another stay (the active day) each subject was asked to engage in a specified physical activity/exercise protocol. The protocol consisted of two separate 2-h morning and afternoon exercise sessions (Table 1). The order of stays was randomized so some subjects had the active day first and some had the normal day first.

Protocol inside room calorimeter

The subjects reported at 0700 to the CRC on scheduled days to stay in the whole-room indirect calorimeter for 24 h. The-room indirect calorimeter is equipped with a bed, a desk, a chair, a toilet and a sink, a telephone, a television and VCR, and an audio system. The calorimeter is an air-tight room (2.6 × 3.4 × 2.3 m, 19 500 l in net volume) with a controlled flow of air into and out of the calorimeter. Parameters such as difference in oxygen and carbon dioxide concentrations entering and exciting air, barometric pressure, air flow purging throughout the chamber, ambient temperature, and humidity were continously measured and data was sent to a computer 60 times/s during the entire experiment. Subjects were free to choose their food from menus provided by CRC dietitians, but the amount and composition of food eaten were measured and nutrient and energy intake calculated. Meals were provided at exact times during the day and subjects were given 30 min to consume a meal. At the end of the 30 min, the subject was asked to return all uneaten food to the CRC personnel. A step exercise platform and a computer-monitored stationary bike were setup inside the chamber. Subjects could choose to walk, step, or bike for exercise if they wished. To record the events such as television viewing, sitting, eating, exercising, sleeping, etc. a set of eight independent push-buttons were assigned for different events. The subject pushed the related

Table 1 Physical characteristics of the non-obese and obese men and women participating in the study[a]

	Men			*Women*		
	Non-obese *n = 38*	*Obese* *n = 13*	*Total* *n = 51*	*Non-obese* *n = 44*	*Obese* *n = 28*	*Total* *n = 72*
Age (years)	34 ± 10	39 ± 10	35 ± 10	36 ± 11	39 ± 7	37 ± 7
Height (cm)	178 ± 7.2	178 ± 5.9	178 ± 6.9[c]	165 ± 5.3	165 ± 7.4	165 ± 6.1
Body mass (kg)	79 ± 9.9[b]	121 ± 15.2	90 ± 21.6[c]	64 ± 9.8[d]	103 ± 19.1	79 ± 23.6
BMI (kg/m^2)	24.9 ± 2.8[b]	38.0 ± 5.4	28.2 ± 6.8[c]	24.2 ± 3.4[d]	37.8 ± 6.1	29.3 ± 8.0
% Body Fat	19.4 ± 7.8[b]	35.2 ± 5.9	23.4 ± 10.1[c]	30.2 ± 8.0[b]	44.6 ± 6.3	36.0 ± 10.1
Fat Free Mass (kg)	63.2 ± 6.4[b]	77.6 ± 6.9	66.8 ± 9.1[c]	44.4 ± 5.3[d]	56.7 ± 8.6	48.7 ± 8.7
Fat Mass (kg)	16.8 ± 5.3[b]	43.4 ± 5.1	22.8 ± 8.6[c]	20.6 ± 3.4[d]	46.3 ± 6.3	30.0 ± 7.8

[a] *mean ± sd, n = 123*
[b] *significantly different from obese men*
[c] *significantly different from women*
[d] *significantly different from obese women*

button at the beginning and released it at the end of each event. The event buttons were constantly monitored and recorded by the computer, together with the measured EE and physical activities on a 24-h basis. In addition, the force platform system and electronic sensors placed under the bed, chair, and inside the television set were able to ensure determining activities such as sitting, viewing television, sleeping, and mechanical work during exercise reliably, as detailed elsewhere.[22,23]

Measurement of energy expenditure and physical activities

Energy expenditure was obtained by measuring the amount of oxygen consumption (VO_2), carbon dioxide production (VCO_2), and urinary nitrogen excretion using the indirect calorimetry technique. Oxygen consumption ($V0_2$) and carbon dioxide production (VCO_2) of each subject were calculated by measuring the changes in oxygen and carbon dioxide contents in the air inside the chamber and by multiplying the flow rate of the purged air times its concentration of oxygen and carbon dioxide.

New techniques were implemented to ensure accuracy and fast response in EE measurements. A special multi-channel air sampling system was designed to obtain an even sampling of the expired gas by the subject. Room temperature and humidity were precisely controlled (temp. $22.5 \pm 0.15°C$, vapor pressure 10.0 ± 2.5 mm Hg). In addition, on-line signal processing and system identification algorithms were used to reduce greatly the random noise and significantly improve the measurement accuracy. The detailed methodology and description of the whole-room indirect calorimeter has been reported earlier.[22] Results from 54 propane and ethanol combustion tests with 1-min measurement interval showed that the system error was less than 0.7% (STD = 0.27% for EE and STD = 0.48% for respiratory quotient tests, $n = 54$) over large O_2 and CO_2 concentration ranges. To our knowledge, these are the most accurate data ever reported using indirect whole-room calorimeter with a measurement interval as short as 1 min. Achieving such high level of accuracy was crucial for the study since higher variation could not only affect measurements of components such as energy expenditure during television viewing, sitting, and other forms of physical activity but total EE as well. It is known that even a very small change in 24-h EE can lead to a significant changes in body weight over time. For example, if energy intake is maintained constant, a 5% reduction in 24-h EE could cause approximately 4 kg per year increase in body weight.

Mechanical work (MW)

MW caused by physical activity and its related increase in EE were determined by the combination of a large force platform system and the chamber. Briefly, any body movement and the associated work were fractionated into three (x, y and z) dimensions. The multiple force transducers installed in the large force platform that covers the entire living area detected these forces and movements. The computer received these signals then computed forces, body displacement, and mechanical work of subjects moving on top of the platform (the floor) during their daily activity on exercises inside the chamber. Results were stored each minute on a 24-h basis. Technical details of the system have been described by Sun and Hill.[22]

Energy expenditure during television viewing (EE_{tv})

EE_{tv} was determined as the average rate of energy expenditure of a subject viewing television when sitting for more than 5 min. Television viewing has been defined as the period of time when this activity was reported by the subject. The subject was required according to this protocol to press a television button when he/she started viewing television and to release it when finished the viewing. This action was double-checked by the body movement and mechanical work values measured by the floor system during television viewing. Furthermore, to avoid accidental situations when a subject started to view television without pushing the television button, a microprocessor-controlled alarm system emitted light and sound signals to remind the subject to push the button. Periods of television viewing in which mechanical power of the subject exceeded 6 W were automatically excluded from calculations. In addition, periods within 2 h of the beginning of the meals, within 15 min after exercise, and the first 2 min after sitting and viewing television were excluded to avoid residual effects on EE by other activities.

Energy expenditure during sitting (EE_{sit})

Sitting was defined as the periods of time spent by the subject in the chair which was sensed by the pressure transducers and the position location function of the floor system. EE_{sit} was determined as the average rate of subject's energy expenditure sitting for more than 5 min. Periods within 2 h of the beginning of the meals, within 15 min after exercise, and the first 2 min after sitting were excluded from calculations.

Energy expenditure during sitting and not viewing television (EE_{sntv})

EE_{sntv} was determined the same way as EE_{tv} except the subject was not viewing television. The differences between EE_{tv}, EE_{sntv} and EE_{sit} enabled us to evaluate separately the effect of television viewing events on total EE.

Energy expenditure during walking (EE_w) and stepping (EE_{stp})

EE_w ad EE_{stp} were determined as the average rate of energy expenditure of a subject performing these forms of physical activity during physical activity/exercise sessions consisting of three 10 min walking bouts (0.6 m/s, 0.9 m/s and 1.2 m/s) and four stepping laps (2 laps/10 s, 3 laps/10 s, 4 laps/10 s and 5 laps/10 s) separated by 10 min breaks.

Resting metabolic rate (RMR)

RMR was determined as the averaged EE when the awake subject was lying motionlessly in bed in the morning after >10 h fasting and overnight sleeping. The resting status was corroborated by the floor system. Some sporadic activities during the measurement were removed by subtracting these components from total EE to improve accuracy. To ensure that the subject was awake during the 30 min measurement period, a small electronic beeper with a touch button to stop beeping has been designed. During the RMR test, the subject had to touch this button with a mild pressure, at least once every 2 min. If he or she left the button unattended while falling to sleep, the beeper was triggered to alert the subject.

Body composition

Body weight was measured to the nearest 0.05 kg by a digital scale. Body fat and fat-free mass (FFM) was determined by hydrodensitometry (underwater weighing). Subjects were weighted underwater while their residual lung volume were measured by a nitrogen-dilution technique.[24] Body fat percentage was calculated from body mass density by using Siri's equation[25] and fat mass (FM) and fat-free mass (FFM) were calculated from body weight.

Statistical analysis

All descriptive statistics are presented as means ± standard deviation (s.d.) Since regression lines relating energy expenditure to metabolic mass do not have zero intercepts,[26,27] regression equations relating measures of energy expenditure to FFM and FM were calculated and used to determine the predicted values. After establishing parallelism of the regression lines by testing homogeneity of slopes, gender and activity (a two-level discrete variables) were added to multiple linear regression models. The residuals of the models reported had a normal distribution. Adjusted by this method rates of energy expenditure are expressed as number of kilojoules (kJ) per minute. The effects of gender, obesity, and activity in the room calorimeter, and their interactions on time of television viewing were assessed by randomized-block analysis of variance (ANOVA) with a factorial structure followed by orthogonal contrasts. Differences in variables between two groups, i.e. obese *vs* lean, men *vs* women, were evaluated by using the paired comparison *t*-test with a two-sided rejection region and a confidence level of 95%.

Results

Among 123 subjects studied, 28 women and 13 men had BMI higher than 30 and were considered obese for the purpose of this study. The remaining participants were classified as non-obese subjects. Subject characteristics are shown in Table 1. On the second stay, subjects' body weight, FFM and fat mass (FM) were not different from those on the first session ($p > 0.05$). RMR and metabolic rates of other physical activities were adjusted for differences in body composition.

Resting metabolic rate (RMR)

The regression equations for metabolic rates with the covariates FFM, FM, gender and activity are presented in Table 2. The group values for adjusted metabolic rates at the experimental conditions are summarized in Tables 3 and 4. FFM alone explained 68% of the variance of RMR. Mean RMR value, adjusted for body

Table 2 Regression equations for resting metabolic rate (RMR) and rates of energy expenditure during television viewing (EE_{tv}), during sitting (EE_{sit}), and during sitting and not viewing television (EE_{sntv}) with the covariates FFM, FM, Gender and Activity (active vs. normal day)

Variable	*Intercept*	*FFM (kg)*	*FM (kg)*	*Gender*	*Activity*	r^2
RMR[d]	0.359 ± 0.088 (P < 0.0001)	0.015 ± 0.046 (P < 0.0001)	0.005 ± 0.0008 (P < 0.0001)	+0.063 ± 0.036 (P = 0.083)	+0.010 ± 0.01 (P = 0.581)	0.729
	0.354 ± 0.87 (P < 0.0001)	0.019 ± 0.0009 (P < 0.0001)	0.0041 ± 0.0008 (P < 0.0001)	+0.063 ± 0.036 (P = 0.082)		0.850
EE_{tv}	0.632 ± 0.099 (P < 0.0001)	0.016 ± 0.0016 (P < 0.0001)	0.0038 ± 0.0009 (P < 0.0001)	+0.109 ± 0.041 (P = 0.008)	+0.057 ± 0.01 (P = 0.0078)	0.708
EE_{sit}	0.711 ± 0.103 (P < 0.0001)	0.016 ± 0.0017 (P < 0.0001)	0.0041 ± 0.001 (P < 0.0001)	+0.104 ± 0.043 (P = 0.0149)	+0.101 ± 0.022 (P < 0.00001)	0.704
EE_{sntv}	0.646 ± 0.092 (P < 0.0001)	0.016 ± 0.0015 (P < 0.0001)	0.0032 ± 0.0008 (P < 0.0001)	+0.097 ± 0.038 (P = 0.082)	+0.069 ± 0.02 (P < 0.0001)	0.856

[a] *the value reported for each term is the parameter estimate ± s.e.. Significance levels are reported in parentheses beneath each term.*
[b] *the values for gender (a two-level discrete variable) represents the difference in energy expenditure between males and females after adjustment for the covariates in the respective models. Positive values signify that males have higher adjusted energy expenditure than females.*
[c] *the values for activity (a two-level variable) represents the difference in energy expenditure between active and normal days after adjustment for the covariates in the respective models. Positive values signify that adjusted energy expenditure were higher during the active day than normal day (see Methods).*
[d] *the multiple linear regression analysis of BMR is performed with and without variable Activity (normal vs. active day)*

Table 3 Resting metabolic rate (RMR) and rates of energy expenditure during television viewing (EE_{tv}), during sitting (EE_{sit}), and during sitting and not viewing television (EE_{sntv}) measured in obese and non-obese men and women during 2 separate 24 h stays in whole room indirect calorimeter (kJ* min^{-1}).[a]

	Men			*Women*			*Men and Women*	
	Non-obese n = 38	*Obese n = 13*	*Non-obese and obese n = 51*	*Non-obese n = 44*	*Obese n = 28*	*Non-obese and obese n = 72*	*Non-obese n = 41*	*Obese n = 82*
RMR	5.33 ± 0.58[b]	5.58 ± 0.77[b,c]	5.39 ± 0.64[b]	5.40 ± 0.52[b]	5.21 ± 0.71[b]	5.32 ± 0.60[b]	5.36 ± 0.62[b]	5.33 ± 0.75[b]
EE_{tv}	6.53 ± 0.83	6.62 ± 0.67	6.55 ± 0.79	6.36 ± 0.52	6.46 ± 0.83	6.40 ± 0.65	6.44 ± 0.68	6.51 ± 0.78
EE_{sit}	6.72 ± 0.0.93	6.70 ± 0.75	6.71 ± 0.86	6.58 ± 0.56	6.68 ± 0.83	6.62 ± 0.67	6.64 ± 0.75	6.68 ± 0.80
EE_{sntv}	6.60 ± 0.78	6.65 ± 0.67	6.61 ± 0.75	6.44 ± 0.50	6.54 ± 0.75	6.47 ± 0.61	6.51 ± 0.65	6.57 ± 0.72

[a] *mean ± sd, n = 123*
[b] *significantly different from EEtv, EEsit, EEsntv*
[c] *significantly different from obese women*

composition, was 1.3% lower in women than in men but the difference was not significant ($p = 0.083$). RMR measured on active days was similar to measured on normal days ($p = 0.571$). Differences in RMR between obese and non-obese participants (4%) were not significant (4%) were not significant ($p = 0.176$). However, RMR was significantly lower in obese women than in obese men ($p = 0.038$). There were marked differences in RMR between the subjects (CV = 13.7%) but intraindividual variations between the two separate 24 h stays were very small and insignificant (*t*-test) in men ($p = 0.953$) and in women ($p = 0.397$).

Energy expenditure during television viewing (EE_{tv})

As Tables 3 and 4 show, EE_{tv} was significantly higher than RMR ($p < 0.001$) and both rates were highly correlated in all subjects ($r = 0.83$). There was no significant difference in EE_{tv} between non-obese and obese participants ($p = 0.699$). Activity was a significant determinant of EE_{tv} was tested in the relationship to EE_{tv} and FFM and FM ($p = 0.008$). EE_{tv} was 0.057 ± 0.01 kJ* min^{-1} (82 kJ/day) higher on the active than on the normal day. Gender was also a significant determinant of EE_{tv} which was 0.109 ± 0.04 kJ/min (157 kJ/day^{-1}) higher in men than in women ($p = 0.008$).

Rate of energy expenditure during sitting (EE_{sit})

As shown in Tables 3 and 4, EE_{sit} was significantly higher than RMR. The differences in EE_{sit}, normalized for body composition, between non-obese and obese participants were not significant ($p = 0.625$). Both, gender and activity, were significant determinants of EE_{sit}. The EE_{sit} rate was 0.104 ± 0.004 kJ/min (150 kJ/day) higher in men than in women. EE_{sit} was 0.101 ± 0.022 kJ/min (145 kJ/day^{-1}) higher on the active day than on the normal day. The differences in EE_{sit} between the active and the normal day were significant in both, men ($p = 0.017$) and women ($p = 0.013$). There was an insignificant ($p = 0.573$) interaction of gender and exercise indicating that the effect of gender on EE_{sit} was independent from the effect of prior exercise. There was no difference between EE_{sit} and EE_{tv} for all participants combined ($p = 0.70$).

Rate of energy expenditure during sitting and not viewing television EE_{sntv})

Body composition normalized EE_{sntv} was significantly ($p < 0.001$) higher than RMR (Tables 3 and 4). EE_{sntv} in

Table 4 Resting metabolic rate (RMR) and rates of energy expenditure during television viewing (EEtv), during sitting (EEsit), and during sitting and not viewing television (EEsntv) measured at normal and active days in men and women during 2 separate 24 h stays in whole room indirect calorimeter (kJ* min^{-1})[a]

	Men		*Women*		*Men and Women*		
	Active n = 51	*Normal n = 51*	*Active n = 72*	*Normal n = 72*	*Active n = 123*	*Normal n = 123*	*Total n = 123*
RMR	5.39 ± 0.59[b]	5.39 ± 0.70[b]	5.37 ± 0.59[b]	5.28 ± 0.62[b]	5.37 ± 0.59[b]	5.33 ± 0.65[b]	5.35 ± 0.62[b]
EE_{tv}	6.67 ± 0.87[c,d]	6.45 ± 0.68	6.53 ± 0.70[e]	6.27 ± 0.58	6.58 ± 0.77[f]	6.34 ± 0.63	6.46 ± 0.71
EE_{sit}	6.98 ± 0.99[c,d]	6.44 ± 0.67	6.78 ± 0.69[e]	6.43 ± 0.60	6.87 ± 0.83[f]	6.44 ± 0.63	6.66 ± 0.77
EE_{sstv}	6.79 ± 0.82[c,d]	6.43 ± 0.63	6.59 ± 0.62[e]	6.36 ± 0.58	6.67 ± 0.72[f]	6.39 ± 0.60	6.53 ± 0.67

[a] *mean ± sd, n = 123*
[b] *significantly different from EEtv, EEsit, EEsntv*
[c] *significantly different from men on normal day*
[d] *significantly different from women on normal day*
[e] *significantly different from women on normal day*
[f] *significantly different from normal day*

Table 5 Time of spontaneous television viewing by non-obese and obese men (n = 53) and women (n = 71) during 2 separate stays (normal and active) in indirect whole-room calorimeter (min)

	Men			*Women*			*Men and Women*		
	Non-obese $n = 38$	*Obese* $n = 13$	*Total* $n = 51$	*Non-obese* $n = 44$	*Obese* $n = 28$	*Total* $n = 72$	*Non-obese* $n = 82$	*Obese* $n = 41$	*Total* $n = 123$
Normal day	162 ± 85^{b}	201 ± 78^{b}	$172 \pm 84^{b,c}$	194 ± 102^{b}	224 ± 107^{b}	206 ± 103^{b}	$179 \pm 93^{b,d}$	217 ± 98^{b}	192 ± 96^{b}
Active day	79 ± 65	107 ± 77	87 ± 69	106 ± 79	122 ± 67	112 ± 75	94 ± 74	117 ± 70	101 ± 73
Average day	121 ± 86	154 ± 90	129 ± 88^{c}	150 ± 99	174 ± 103	159 ± 101	136 ± 94^{d}	168 ± 99	147 ± 96

[a] *mean ± sd, n = 123*
[b] *significantly different from active day*
[c] *significantly different from women*
[d] *significantly different from obese*

obese subjects was similar to non-obese subjects ($p = 0.63$). EE_{sntv} in both men ($p < 0.001$) and women ($p < 0.001$) on the active day was higher than on the normal day. Activity was a significant determinant of EE_{sntv} ($p < 0.001$). The differences between EE_{tv} and EE_{sntv} in men (1.0%) and women (1.1%), in obese (1.0%) and non-obese subjects (1.1%), and on active (1.4%) and normal days (0.8%) were insignificant.

Time of television viewing

Table 5 summarizes the duration of self-selected television viewing by the participants during their two separate stays in the whole-room indirect calorimeter. Average time of television viewing was 146 min, and it was 28 min longer in women than in men (p = 0.022). Obese men and women spent on average 32 min more viewing television than non-obese subjects ($p = 0.008$). On both normal and active days obese subjects spent more time viewing television than non-obese subjects and the difference was higher on normal day (217 ± 98 min *vs* 179 ± 94, $p = 0.04$) than on active day (117 ± 70 min *vs* 94 ± 74 min, $p = 0.09$). The difference between normal and active day were highly significant ($p = 0.0001$) in both obese and non-obese participants. Obese women spent 21 min more than obese men and non-obese women spent 26 min more than non-obese men viewing television. Both men and women spent

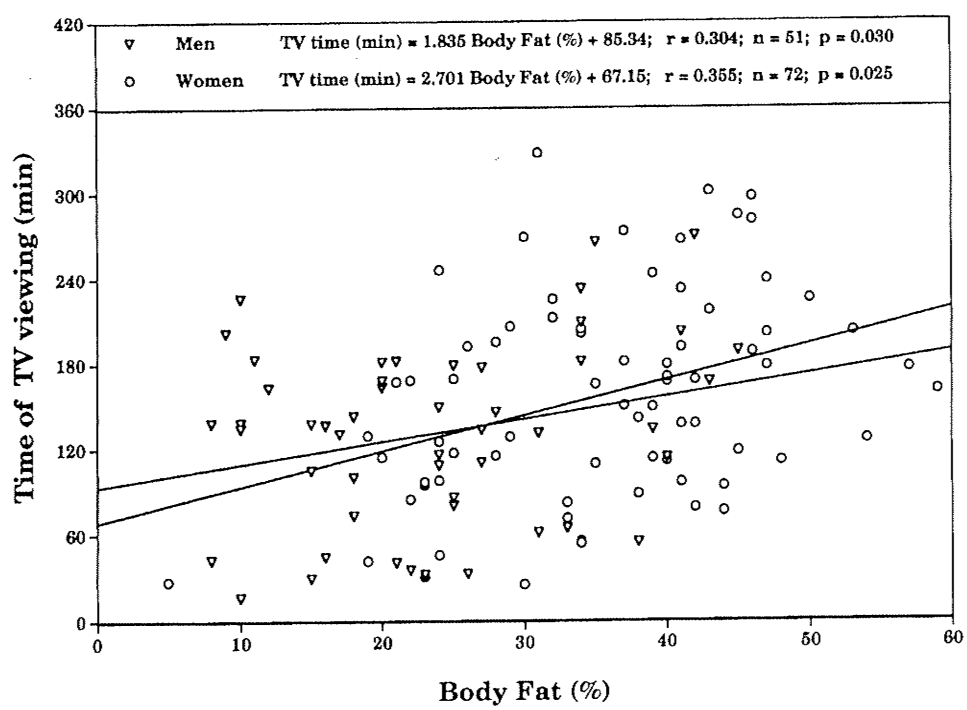

Figure 1 Time of television viewing in relation to body fatness (%) in men ($n = 51$) and women ($n = 72$) during two separate 24-h stays in a whole-room indirect calorimeter. Each point is an average for one of the 123 subjects.

almost 100 min more on this activity on the normal day than on the active day ($p < 0.0001$). Women spent more time than men viewing television on both normal and active days. There was substantial variation in time of television viewing between subjects (CV = 65%). Yet, we did find a significant positive correlation between body fatness (BF%) and time of television viewing (Figure 1). This correlation was stronger in women ($p < 0.025$) than in men ($p < 0.030$).

Discussion

The present study is the first to quantify energy expenditure during self-selected television viewing in obese and non-obese adults. We also examined rates of energy expenditure during inactive sitting and non viewing television, and during sitting and performing other forms of physical activities such as writing and reading with the television set turned off. The rates of energy expenditure during television viewing while sitting (EE_{tv}) and during other forms of sedentary activities (EE_{sit}, EE_{sntv}) were significantly higher than RMR in both men and women, obese and non-obese. On the other hand, RMR and rates of EE_{tv}, EE_{sit}, and EE_{sntv} adjusted for differences in body composition were approximately 2% higher in men than in women, but the difference was not significant. Similar difference in RMR between men and women has been reported by Ferraro *et al.*[28]

Menstrual function was recorded but not controlled for in this study. Energy expenditure has been reported to be significantly higher in women during the luteal phase of the ovulatory cycle in some studies,[29–30] but not in others.[31–33] Therefore, to minimize the potential confounding effect of the menstrual cycle on energy expenditure in women, we analyzed differences in EE between active and normal days in the subset of women. Adjusted RMR was not significantly different between these two days ($p = 0.675$) suggesting that the menstrual cycle did not affect intraindividual RMR differences in women. Furthermore, since other sedentary forms of physical activity were measured during the same 24-h period as RMR, individual differences in EE_{tv}, EE_{sit}, and EE_{sntv} between the normal and the active day in women were probably caused by factors other than the menstrual cycle. It has been shown that in women EE is not changing significantly during any 24-h period of the menstrual cycle.[33] We cannot, however, exclude the possibility that the menstrual cycle could affect differences in rates of energy expenditure between men and women.[28]

It has been suggested that television viewing may promote weight gain by lowering resting energy expenditure.[19] In this study we did not detect any significant differences in EE between sitting and viewing television and sitting for other sedentary forms of physical activity such as reading or writing in adult men and women, both obese and non-obese. Lack of reports on the effect of television viewing on energy expenditure in adults make it difficult to compare our study with others. In one of the two existing reports examining EE during television viewing in children, Dietz *et al.*[20] suggested that television viewing does not alter resting metabolic rate. In contrast, in a study by Klesges *et al.*,[19] children showed significant decrease in energy expenditure during television viewing in comparison with rest. The authors concluded that television viewing has a profound lowering effect on metabolic rate and may be a mechanism explaining the relationship between obesity and duration of television viewing. Our results offer explanation which is in agreement with the notion of Dietz *et al.*[20] who concluded that television viewing in children may not contribute to obesity by reduction in RMR.

Results from this study and from other studies (M. Sun, unpublished data) that involved over 400 subjects staying inside our whole-room indirect calorimeter indicate that in adults RMR is significantly lower than energy expenditure of other sedentary forms of physical activity. These results are similar to results in adults reported by others,[28,34] but in contrast to both cited studies in children.[19,20] One potential explanation, in addition to the age difference, might be the different experimental approach used. In our approach resting metabolic rate (RMR) was measured when awake subjects were laying in bed motionless immediately after 10 h fasting and overnight sleep. In the studies by Klesges *et al.*[19] and Dietz *et al.*,[20] RMR were measured in awake children who reported to the study site in the morning and were laying in a reclining position on a bed or sitting on a reclining chair. An alternative explanation of the discrepancies may be the calorimetry method used and the time of measurement. In their approach, measurements were conducted using a canopy system consisting of a helmet enclosing the head, each session lasted 2 h, and the child was instructed to view television. Our subjects spent approximately 48 h in the whole-room indirect calorimeter on two separate days and EE_{tv} was obtained during self-selected television viewing while sitting in a comfortable chair without body movement. Controlled environment within the whole-room indirect calorimeter, such as isolation of disturbance by ambient O_2, CO_2 composition, isolation of sound and visual disturbance, guaranteed fresh air inlet, and stable temperature, enabled us to obtain EE_{tv} that is closer to naturalistic situations such as viewing television at home.

The most frequent sedentary activity among adults in the United States is television viewing. The Nielsen Report[5] indicated that adult men and women watch approximately 3.7 and 4.7 h a day, respectively. Average viewing time was shorter in participants of this study. One possible explanation is that in our approach only the television periods when subjects did not have any significant physical activity, monitored by the large force platform, were included in calculations. In addition, the first five minutes of each television viewing event was excluded from the viewing time. Another explanation is that although our system measured actual time of television viewing precisely and did not rely on participant's subjective report, it did not provide living environment totally equivalent to the natural living environment. Similar to the Nielsen report, we found that television viewing time was significantly longer in women than in men. Both obese women and men were viewing television for longer time than non-obese participants. There was a linear relationship between body fatness and time of television viewing. These observations confirm previous reports showing strong correlation between self-reported time of television viewing and prevalence of obesity in adult men and women.[6,7] However, since this was not a retrospective study, cause-and-effect conclusions regarding time of television viewing and obesity cannot be reached. According to Dietz and Gortmaker,[35] the relationship between television viewing and obesity fulfills many of the classical criteria necessary for a casual association. Thus, it is plausible that the passivity of television viewing leads to obesity, and obesity leads to television viewing – a cycle of mutual interaction and reinforcement.

Although EE_{tv} was not lower than EE_{sit}, it was still significantly lower than many other daily physical activities. In this study, EE_{act} during daily physical activities such as walking or stepping were 2 to 4-fold higher than EE_{sit} or EE_{tv}. Since EE_{tv} and EE_{sit} were among the lowest EE components in daily activities, prolonged television time would certainly cause a significant reduction in total EE. As indicated in the results section, obese people spent significantly more time viewing television than non-obese people. For example, the average time differences in television viewing between obese and non-obese participants were approximately 30–40 min. The difference between EE_{tv} and the energy expenditure during the lightest form of physical exercise (walking at 0.6 m/s or 1.34 mile/h) performed by the participants of our study was 9.13 kJ/min. Therefore, substituting 30 min of slow pace walking with television viewing would cause approximately 275 kJ/day of positive energy balance in an average adult person. This surplus of energy could result in an increase in body weight when the energy intake remains constant. If we assume 80% of weight gain is fat and 20% is FFM, and fat is stored with 97% efficiency and FFM with 90% efficiency, the excess of 275 kJ/day will cause a gain of 3 kg per year simply because of this difference in a form of activity. In addition, equivalent substitution of more vigorous physical activities and exercise by television viewing could cause a reduction in mobilization of body fat occurring in individuals who would otherwise participate in these activities.

In order to minimize the effect of prior exercise on the rates of EE, we removed the first 5 min of each sedentary activity from our calculations. Nevertheless, we observed a significant augmentation of EE_{tv}, EE_{sit} and EE_{sntv} on the active day. These results suggest that previous exercise or other vigorous physical activity, may have a lasting thermic effect on sedentary EE rates. Similar relationship has been reported by others.[36,37] This effect, however, was insignificant for RMR which was measured approximately 14 h after the exercise session.

Although large differences in time of television viewing existed among experimental groups, these differences were not always statistically significant, mainly due to large inter-individual variations. This indicates that while there is certainly a positive correlation between time of television viewing and obesity, other factors such as lifestyle and occupation could also influence the time of television viewing.

There are several potential interpretations of our findings in relation to time of television viewing and energy balance in adults participating in the study. First, there is an association between time of television viewing and obesity measured by BMI and percentage of body fat. Examination of this association with both variables treated as continuous measurements shows a linear relationship. This association is true for both men and women. Second, the observation can be made that women tend to view television more than men and this observation seems to be accurate in both obese and non-obese individuals. Displacement of more vigorous physical activities by television viewing may affect energy balance. Third, the implications of these findings for duration and energy expenditure during self-selected television viewing in free-living subjects are difficult to assess and require further investigations.

In summary, the absence of the effect of obesity on the rate of energy spent viewing television seems to exclude the possibility that television viewing may cause obesity by lowering the rate of energy expenditure when compared to similar sedentary activities. On the other hand, our findings suggest that obese adults tend to view television for a longer time than non-obese persons and this behavior is more prevalent in women than in men. Adults who choose even as short as half hour daily substitution of various form of physical activity with television viewing could affect significantly their total daily energy balance and body weight.

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